



North American Black Carbon Emissions Estimation Guidelines

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Project Overview

- CEC Project “North American Black Carbon Emission Inventory Guidelines” initiated in November 2013
- Objectives
 - Thorough review and comparison of data and methods
 - Establishment of consensus methodologies to harmonize and improve North American black carbon emissions inventories
 - Incorporation of these into a user-friendly guidance document
- Steering Committee
 - Orlando Cabrera-Rivera, CEC
 - Luis Conde Alvarez, Instituto Nacional de Ecología y Cambio Climático (INECC)
 - Terry Keating, U.S. EPA
 - John Moritz & Francois Lavallee, Environment Canada



Project Team

- **ERG**
 - John Koupal - Onroad
 - Paula Fields Simms–Residential
 - Richard Billings–Marine/rail/aircraft
 - Rick Baker– Nonroad
 - Regi Oommen– Industrial/Energy
 - Ted Hogan– Expert Consultations
 - Gopi Manne– Literature Review / Guidelines Document
- **Veronica Garibay-Bravo (Consultant/Querétaro, Qro) - Mexico Lead**
- **Dr. Joyce Penner (Consultant/Univ. of Michigan) – Biomass**



Project Tasks

- **Task 1:** Review existing black carbon data and methodologies; initial recommendations for North America (Complete)
- **Task 2:** Solicit expert review; consensus methods to harmonize and improve North American black carbon emissions inventories (Complete)
- **Task 3:** Develop guidance document (Draft under review; Final Spring 2015)



Guiding Principles

- Guidance document should be pragmatic about differences between countries in resources, data, and policy needs
- Should identify best-practice approaches, consider how each country can adopt, and include as alternatives or a staged approach for short-term adoption
- Recognize need to identify low-cost recommendations for improving black carbon inventories in Mexico
- The approach to developing emissions inventories depends on the final use of the inventory (“use cases”)
- The guidance document must ultimately be understood and accepted by end users



Major Sectors and Subsectors

- Biomass Burning
 - Open Burning (e.g. Wildfires)
 - Agricultural Burning
- Mobile Sources
 - On-road
 - Non-road
 - Locomotives
 - Marine
 - Aviation
- Residential
 - Cookstoves, etc.
- Industrial/Energy
 - General
 - Brick kilns (Mexico)
- Other Sources
 - Commercial cooking/charbroiling
 - Cremation
 - Structure and vehicle fires
 - Municipal solid waste burning



Task 1: Review & Initial Recommendations

- Literature Search and Review
 - Databases, abstracts, documents
 - Focused on major, comprehensive inventories, including underlying particular matter (PM) inventories, for North America & Europe
- Divided review into major sectors and primary subsectors
 - Summarized BC and PM inventory approaches
 - Evaluated North American approaches relative to Europe
 - Following IPCC approach, developed general recommendations based on “Tiers”



Master Candidate Document List

- On-line databases → 8,000 studies
- 2004 and later → 1,200 studies
- Available abstract, applicable title → 600 studies
- Final list for review → 140 studies
- Focused on Comprehensive Studies:

Country	Black Carbon Inventory	Underlying PM Inventory
Canada	Assessment of Emissions and Mitigation Options for Black Carbon, Arctic Council, 2011	• NPRI
U.S.	EPA Report to Congress, 2012	• 2002, 2005, 2011 U.S. NEI • RPO Inventories (Biomass)
Mexico	Supporting National Planning of Short-lived Climate Pollutants in Mexico, 2013	2008 Mexico NEI
Europe	EMEP/EEA Air Pollutant Emission Inventory Guidebook, 2013	
Global	• A Technology-based Global Inventory of Black and Organic Carbon Emissions from Combustion (Bond 2004) • Extension of the GAINS model to include SLFCs (Heyes 2011)	



Initial Observations & Judgments

- BC guidelines need to focus on underlying PM emission inventories
- Estimation of BC inventories by speciations of bottom-up PM emissions is the global standard for nearly every sector, as follows:

$$\text{Black Carbon Mass Emissions} = \text{PM 2.5 Emission Factor} \times \text{Activity (or Activity Surrogate)} \times \text{Speciation Factor}$$

- Emissions data can often be shared across countries, accounting for country-specific controls and factors.
- Activity data are country-specific, and generally obtained from data compiled outside of the agencies responsible for emission inventory development.
- The guidelines should therefore present best practice emission factors by individual sector, to allow inventory developers to focus resources on gathering country-specific activity data.



Methods Evaluation

- North American approaches evaluated vs. EMEP/EEA Tiers (1, 2, 3)
- Example evaluation matrix:

Sector/Subsector: Mobile Sources/On-Road

	Euro Tier 1	Euro Tier 2	Euro Tier 3	< Tier 1	Tier 1	Tier 2	Tier 3	> Tier 3
Method	Aggregate fuel based PM	Refined fuel-based PM w/ speciation	Detailed bottom-up PM w/speciation				Canada ACTF; Mexico NEI (MOBILE6)	EPA RTC (MOVES calculates EC directly)
Emission Factors	Single fuel-based factor	Technology-specific fuel-based	BC/EC emission factors by vehicle class, model year/standard			Canada ACTF & Mexico NEI (MOBILE6)	EPA RTC (MOVES)	
Activity	Total fuel consumed	Fuel consumed by technology	VMT by vehicle class, roadway, speed				EPA RTC (MOVES); Canada ACTF; Mexico NEI	
Speciation	N/A	Technology-specific factor	Technology-specific factor				Canada ACTF; Mexico NEI (SPECIATE)	EPA RTC (MOVES w/speciation by activity)



Initial Recommendations

- Develop initial recommendations for North American Tiers based on data available in Canada, U.S. and Mexico – example:

Sector/Subsector: Mobile Sources/On-road

	Recommended North American Tier 1	Recommended North American Tier 2	Recommended North American Tier 3
Method	Aggregate fuel-based approach, based on a single national estimate of fuel consumption (by fuel type, i.e. gasoline, diesel, CNG, etc.) by calendar year. Off-model calculation.	Refined fuel-based approach, based on estimates of fuel consumption by fuel type and vehicle class, (i.e. car, light truck, bus, heavy truck). Off-model calculation.	Detailed activity-based approach, using MOVES customized to individual country emission standards and using country-specific data on vehicle activity etc.
Emission Factors	MOVES aggregated to a single fuel-based black (elemental) carbon emission factor, by calendar year. For Canada and Mexico, apply MOVES International approach to adjust for differences in vehicle emission standards	MOVES aggregated to a fuel-based black (elemental) carbon emission factor, by vehicle class and calendar year. For Canada and Mexico, apply MOVES International approach to adjust for differences in vehicle emission standards	Use MOVES directly to estimates black (elemental) carbon emission factor. For Canada and Mexico, develop MOVES International to account for differences in vehicle emission standards. Customize model with country-specific inputs for VKT, average speeds, fuels, vehicle age, and meteorology
Activity	Total fuel consumed – by fuel type only (gasoline, diesel, CNG, etc.)	Fuel consumed by vehicle class and calendar year	VMT or VKT by vehicle class, roadway and average speed
Speciation 11	Not needed, if MOVES elemental carbon emission factor is used	Not needed, if MOVES elemental carbon emission factor is used	Not needed, if MOVES elemental carbon output is used



Task 2: Expert Consultations

- Expert panel recruited for coverage by emissions sectors, countries
- Results of Task 1 shared for review
- Series of webinars held in Fall 2014 to solicit input
 - Online surveys sent prior to each webinar
- Meeting with Mexico Panel Members & INECC held in Mexico City
- Written comments also requested

Expert Panel Members

Name	Employer/Organization
José Andrés Aguilar	INECC (Mexico)
Luisa Molina	Molina Center of Energy and the Environment (Mexico)
John Crouch	Hearth, Patio and Barbeque Association (U.S.)
Michelle Bergin	Duke University (U.S.)
Santa Centeno	INECC (Mexico)
Xochitl Cruz Nunez	UNAM (Mexico)
Beatriz Cardenas	Comision Ambiental de la Megalópolis (Mexico)
Luis Gerardo Ruiz Suarez	UNAM (Mexico)
Carlo Trozzi	Techne Consulting (Italy)
Karin Kindbom	IVL Swedish Environmental Research Institute (Sweden)
Vankatesh Rao	U.S. EPA/OAR (U.S.)
Darrell Sonntag	U.S. EPA/OAR (U.S.)
Nancy French	Michigan Tech Research Institute (U.S.)
Jessica McCarty	Michigan Tech Research Institute (U.S.)
Wei Min Hao	U.S. Forest Service (U.S.)
Jim Jetter	U.S. EPA/ORD (U.S.)
Bob Yokelson	University of Montana (U.S.)
Min Huang	Caltech/JPL (U.S.)
Don Stedman	University of Denver (U.S.)
Serena Chung	Washington State University (U.S.)
Sean Raffuse	Sonoma Technology, Inc. (U.S.)
Fang Yan	Argonne National Laboratory (U.S.)
Brooke L. Hemming	U.S. EPA/ORD (U.S.)
Edward Hyer	Naval Research Laboratory (U.S.)
Abraham Ortinez	INECC (Mexico)
Jason Blake Cohen	National University of Singapore (Singapore)
Peter Sheldon	Global Fire Monitoring Center (Germany)
Joshua Schwarz	CIRES/NOAA (U.S.)
Steigvile Bycenkiene	Center for Physical Sciences and Technology (Lithuania)
Savitri Garivait	JGSEE-KMUTT (Thailand)
Matthew Johnson	Carleton University (Canada)



Expert Panel Input - Highlights

- Reflect that speciation factors are a major source of uncertainty in BC inventories
- Address uncertainty
- Reflect recent updates in Mexico (e.g. 2013 SNAP)
- Address temporal resolution
- Include newer studies, esp. for Biomass
 - Since EPA Report to Congress, updated methods contained in the biomass burning section of the U.S. NEI for 2008 and 2011
- Add Municipal Solid Waste burning as a subsector



Task 3: Develop Guidelines

- Guidelines for practitioners to produce BC inventories for major subsectors
- Approaches provided for Tier 1 / 2 /3 , depending on purpose of inventory and data availability

Tier	National Reporting	Regional Inventories	Impact Analyses	Mitigation Analyses
1	✓	✓		
2	✓	✓		✓
3		✓	✓	✓

- For each Tier, sources of activity, emission factor and speciation data identified for Canada, U.S. and Mexico
- Schedule
 - Draft complete – under review
 - Final Spring 2015



Guidance Document Outline

- Overview of Methods Review & Expert Panel Input
- Use of the Guidelines
 - Inventory Use Cases
 - Considerations: Speciation, Spatial/Temporal Resolution
 - Organization: Tier Framework
- Black Carbon Estimation Methods (by subsector)
 - Source Category Description
 - Tier 1, Tier 2 & Tier 3 Methods for estimating emissions
 - Tier 1, Tier 2 & Tier 3 Data Sources for Canada, United States & Mexico: Activity, Emissions Factors, Speciation Factors
- Emissions Data Management
- Validation & Uncertainty
- Recommendations for Further Research

Example : Recommended Data Sources by Country & Tier (Agricultural Burning)

Parameter	Canada	U.S.	Mexico
Tier 1			
Average values for: • Area burned • Yield (avg.) • Residue: yield • Dry matter content • Portion of residue burned • Combustion factor	<ul style="list-style-type: none"> • Area burned (McCarty 2011, remote sensing) or local agency reports • Residue loading by crop: EMEP/EEA 2013, Table 3-2; Schreuder and Mavko 2010; van Leeuwen et al. 2014; WRAP 2005 • Combustion factor data: Van Leeuwen et al. 2014; Akagi et al. 2011 		<ul style="list-style-type: none"> • Area burned: National Union of Sugarcane Harvesters (<i>Unión Nacional de Cañeros A.C.</i>), <i>Estadísticas de la Agroindustria Azucarera Nacional</i> • Annual production per crop: Agriculture and Food Produce Information System (SIACON)(SAGARPA 2013)
Emission factor (PM _{2.5})	Table 3-1 (EMEP/EEA 2013); Schreuder and Mavko 2010; van Leeuwen et al. 2014; Akagi et al. 2011; WRAP 2005		Akagi et al. 2011 For sugarcane: Hall et al. 2012
Speciation factor (BC)	Average BC fraction: SPECIATE database (Figure 4-1, EPA 2013a; use EC factor for BC); WRAP 2005		Average BC fraction: SPECIATE database (Figure 4-1, EPA 2013a; use EC factor for BC)
Tier 2			
By crop type: • Area burned • Yield (avg.) • Residue: yield • Dry matter content • Portion of residue burned • Combustion factor	<ul style="list-style-type: none"> • Area burned (McCarty 2011, using remote sensing) and local agency reports • Residue loading by crop: Schreuder and Mavko 2010; van Leeuwen et al. 2014; 2002 Fire Emission Inventory for the WRAP Region—Phase II report 2005 • Combustion factor data: van Leeuwen et al. 2014; Akagi et al. 2011 		<ul style="list-style-type: none"> • Area burned: National Union of Sugarcane Harvesters (<i>Unión Nacional de Cañeros A.C.</i>), <i>Estadísticas de la Agroindustria Azucarera Nacional</i> • Annual production per crop: Agriculture and Food Produce Information System (SIACON) (SAGARPA 2013) • Residue loading by crop and combustion factor data: none available
Crop-specific emission factor (PM _{2.5})	Schreuder and Mavko 2010; van Leeuwen et al. 2014; Akagi et al. 2011; WRAP 2005		For sugarcane: Hall et al. 2012
Crop-specific speciation factor (EC/BC)		See Tier 1	
Tier 3			
By crop type: • Area burned • Yield (avg.) • Residue: yield • Dry matter content • Portion of residue burned • Combustion factor	<ul style="list-style-type: none"> • Area burned (McCarty 2011, using remote sensing) and local agency reports • Residue loading by crop: Schreuder and Mavko 2010; van Leeuwen et al. 2014; WRAP 2005 • Combustion factor data: van Leeuwen et al. 2014; Akagi et al. 2011 		See Tier 2
Crop-, climate, and soil-specific emission factor (PM _{2.5})	Schreuder et al. 2010; van Leeuwen et al. 2014; Akagi et al. 2011; WRAP 2005		For sugarcane: Hall et al. 2012
Crop-specific speciation factor (BC)		See Tier 1	



Recommended Black Carbon Inventory Improvements - Highlights

- Develop BC emission factors directly
 - Current speciation approach increases error
- Biomass
 - Improved satellite instruments
 - Spatially accurate fuel load data
 - Account for moisture
- Onroad
 - Improve vehicle activity data in Mexico & Canada
 - Adapt MOVES emission rates to Mexico & Canada
- Nonroad
 - Develop standardized source of population & activity in Mexico & Canada
 - Develop more representative emissions factors for aircraft, marine vessels and locomotives



Recommended Black Carbon Inventory Improvements – Highlights, Cont.

- Brick Kilns
 - Develop brick production & efficiency estimates by region in Mexico
 - Develop emission factors by wood & fuel oil
- Residential
 - Conduct surveys of wood use by municipality
 - More representative emissions factors for open fires and cookstoves



Summary

- The Commission for Environmental Cooperation (CEC) is sponsoring the development of Black Carbon emissions estimation guidelines for North America
- Guidelines are based on review of Black Carbon & underlying PM inventories in North America, Europe and Asia
- Guidelines suggest methods and data sources for major emission sectors/subsectors in Canada, Mexico and the United States
- Following IPCC template, 3 Tiers are defined based on inventory purpose and data availability
- Final guidelines will be available Spring 2015



Contacts

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